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(54) Method of selecting automatic operation mode of working machine

(57) The invention is directed to a method of controlling a working machine in a construction equipment, wherein a path of a distal end of a tip working machine (3) such as a bucket is automatically controlled to follow a target path by an actuator controlling means. According to the invention it is automatically determined whether the tip working machine (3) is excavating in a pushing direction or a pulling direction in accordance with an operating condition.

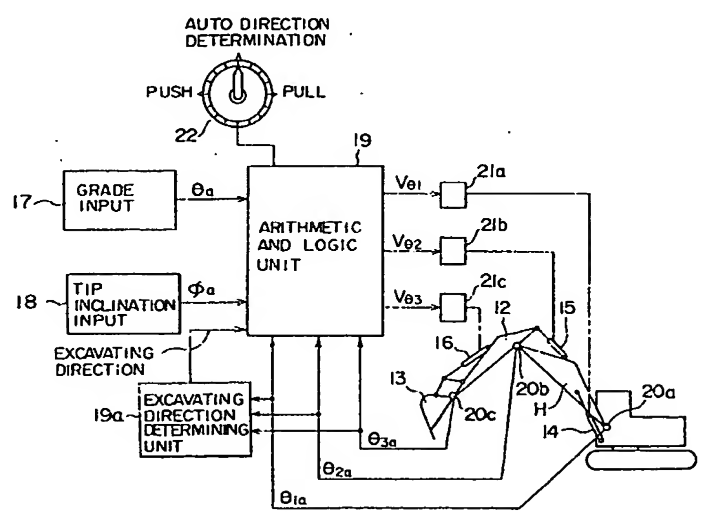

FIG. 12

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Description

Technical Field

The present invention relates to a method of selection an automatic operation mode of a working machine, whereby whether the control of an angle to the ground of a tip working machine with a bucket or the like should be carried out is automatically determined without setting through an input by an operator in construction equipment with a link-type working machine such as a hydraulic power shovel, wherein path control of the working machine is carried out.

Background Art

Fig. 1 shows a working machine of a hydraulic power shovel; 1 is a boom, 2 is an arm, 3 is a bucket, 4 is a boom cylinder, 5 is an arm cylinder, and 6 is a bucket cylinder. The boom 1, the arm 2, and the bucket 3 are turned by extending and contracting the cylinders, causing a distal end of the bucket 3 to draw a predetermined path for excavation.

Conventionally, in automatic excavating path correction work by a hydraulic power shovel on a slope, as shown in Fig. 2A, there are the following two modes; in one mode (nose-fixed mode), the two axes, namely, the boom 1 and the arm 2, are interlocked to make the bucket nose excavate and finish a flat surface, and in the other mode (fixed-angle to the ground mode), three axes, namely, the boom 1, the arm 2, and the bucket 3 are interlocked as shown in Fig. 2B to perform excavation and finish by a bottom surface of the bucket. Before beginning automatic operation, an operator must select between these two modes through a switch or the like.

As a prior art for automatically selecting the modes, there is one disclosed in Japanese Patent Laid-Open No. 2-47432 publication, wherein a boom angle θ_1, an arm angle θ_2, a bucket angle θ_3, a body inclination θ_0, and a target excavating grade θ shown in Fig. 3 are entered, an angle to the ground β of the bottom surface of the bucket with respect to the flat surface, which is to be excavated, at the beginning of the automatic operation is determined from a formula (1) below, and the computation result is compared with a predetermined value, thereby automatically determining the mode.

$$\beta = 3/2\,\pi - (\theta_0 + \theta_1 + \theta_2 + \theta_3 + \theta + \alpha) \tag{1}$$

(where α is a nose angle of the bucket)

Generally, in the case of the bucket used for the hydraulic power shovel, a standard tooth bucket shown in Fig. 4A needs to be replaced by various special buckets according to each work. On the other hand, however, a slope finishing bucket shown in Fig. 4B alone comes in an infinite number of shapes, and there are more buckets, which are produced at general iron works, than genuine buckets produced by construction equipment manufacturers, those produced by general iron works varying in dimensions from one bucket to another except for pin intervals of the buckets. In other words, the use of a method, wherein the mode is determined by determining the angle to the ground β of the bucket bottom surface, poses a problem in that the nose angle a of the bucket must be corrected each time the bucket is changed except a predetermined bucket is used.

Further, when automatic operation is performed for other purposes than excavation, if the position of a hook is linearly moved in suspension work, for example, as shown in Fig. 5, the automatic determination according to the mode determination method described erroneously concludes that it is the nose-fixed mode because of a significant difference between a target direction of movement and an orientation of the angle to the ground β of the bottom surface of the bucket. This presents a problem in that the hook point moves as indicated by a solid line rather than moving along a path which the operator intends.

Hence, in order to hold the current angle to the ground β when the direction of the movement of the working machine is given, the bucket 3 must be turned either to a dump truck side or an excavating side. For instance, a shown in Fig. 6A, if the angle of movement of the bucket on the excavating side is small, then it soon becomes impossible to hold the angle to the ground β in the fixed-angle to the ground mode; therefore, it is very likely that the operator's intention is the nose-fixed mode. On the other hand, if a bucket attitude angle γ, which is a relative attitude of the bucket 3 with respect to the arm 2, is large as shown in Fig. 6B, then the resulting path partially extends beyond (as shown by a hatched area) an arc drawn by the bucket nose point in the nose-fixed mode wherein the arm 2 is turned without moving the bucket 3; therefore, a target excavating surface is ruined in the hatched area during automatic operation. Hence, it is very likely that the operator's intention in this case is the fixed-angle to the ground mode. Therefore, it is necessary to calculate these two possibilities and determine the automatic operation mode according to the magnitude of the calculated values.

Furthermore, as an art for automatic operation in the power shovel, for example, there is one disclosed in Japanese Patent Laid-Open No. 2-221527 publication, which comprises an actuator controlling means, which controls actuators for an excavator, a working machine attitude detecting means, which detects the attitude angles of the boom, arm, and tip working machine of an excavating machine, a grade input means, which gives a target excavating grade for a surface to be excavated by the tip working machine, a distal end inclination input means, which gives a target inclination of the tip working machine with respect to a reference plane, and an actuator operating amount computing means, which computes an operating amount for moving the tip working machine at a determined specific speed with the given inclination and the given excavating grade in response to a detected value received from the working machine attitude detecting means and command values received from the grade input means and the tip inclination input means, and supplies the computed value to the actuator controlling means.

In such a control apparatus, however, it is necessary to specify input signals including a grade input, control inclination input, and excavating direction input for the excavating conditions of a slope surface by the time the automatic operation is begun. Furthermore, there is a problem in that the operating for entering the input signals is easily forgotten and all inputs must be checked for correctness each time before the automatic operation is started.

Disclosure of the Invention

It is an object of the present invention to provide a method whereby the operation mode can be automatically determined without the need of determining the angle to the ground β formed by the bottom surface of the bucket and a target grade, the need for correcting the specific nose angle α even when the bucket is replaced by any optional bucket of a special shape, the path control intended by an operator can be better performed automatically even when the suspension work is performed by a hook attached to the rear of the bucket since the operation mode is automatically determined by an allowable angle to the ground and the attitude of the nose, the arithmetic processing can be performed easily, and the automatic determination of the operation mode can be performed more easily.

It is another object of the present invention to provide a method whereby operator fatigue from operation is reduced to a minimum and operation errors are prevented during excavating work by entering the signals for the excavating direction among the signals entered during the excavating work.

According to the aspect of the present invention, since it is an almost established fact that the excavation is in the pulling direction when the distal end of the working machine at the beginning of the excavation is positioned at the back of a working area or in the pushing direction when it is positioned at the front, the working area is divided into two areas A and B by a boundary; a position detecting means provided on a working machine, which can be operated automatically, determines to which of these two areas A and B a working condition such as the angle and position of the working machine belongs, thus determining whether the excavation is in the pushing direction or the pulling direction in accordance with the determination result. For determining the direction of the excavation, priority may be given to a command received from an external input switch.

Brief Description of the Drawings

Fig. 1 is a configuration explanatory view which shows the working machine of the hydraulic power shovel; Fig. 2A is a configuration explanatory view which shows the nose-fixed mode; Fig. 2B is a configuration explanatory view which shows the fixed-angle to the ground mode; Fig. 3 is a work explanatory view of the prior art; Fig. 4A is a side view which shows the standard tooth bucket; Fig. 4B is a side view which shows the slope surface bucket; Fig. 5 is a work explanatory view which shows the suspension work by the bucket; Fig. 6A is a work view which shows a state wherein the possibility of being the nose-fixed mode is high; Fig. 6B is a work view which shows a state wherein the possibility of being the bucket fixed-angle to the ground mode is high.

Fig. 12 is a block diagram which shows the embodiment of the present invention; Fig. 13 is an explanatory view of the attitude of each component of the working machine; Fig. 14 is a work explanatory view which shows a case wherein the working direction is divided into two in accordance with the angle of the arm; Fig. 15 is an explanatory view which shows two-dimensional a case wherein the working direction is determined in accordance with the angle of the arm; Fig. 16 is an explanatory view which shows two-dimensionally a case wherein the working direction is determined in accordance with the angle of the arm and the angle of the boom; Fig. 17 is an explanatory view which shows two-dimensionally a case wherein the working direction is determined by conversion to an x-y coordinate; Fig. 18A and Fig. 18B are other explanatory views which show two-dimensionally a case wherein the working direction is determined by conversion to an x-y coordinate; and Fig. 19 is a flowchart for determining the working direction by means of the external input switch.

Fig. 12 is the block diagram which shows the embodiment. For the sake of the description given below, the angles and positions of the individual components of the power shovel are defined as shown in Fig. 13. Specifically, the turning angle of a boom 11 is defined as θ_1, the turning angle of an arm 12 as θ_2, the turning angle of a bucket 13 as θ_3, the

inclination of the bucket 13 with respect to the horizontal surface (reference surface) as ϕ, the length of the boom 11 as L_1, the length of the arm 12 as L_2, the length of the bucket 13 as L_3, the longitudinal position of the distal end of the bucket 13 as x, the vertical position of the distal end of the bucket as y, and a target excavating grade as θ.

In such a configuration, a grade command θa from a grade input means 17, a bucket inclination command ϕa from a distal end inclination input means 18, a detected value $\theta_1 a$ of the boom angle, a detected value $\theta_2 a$ of the arm angle, and a detection value $\theta_3 a$ of the bucket angle from working machine attitude detecting means 20a, 20b, and 20c, respectively, are supplied to an actuator operating amount computing means 19. This actuator operating amount computing means 19 calculates a target inclination of the bucket 13, a target path of the nose, and an actual inclination and an actual path of the bucket 13, then it calculates flow command values $V\theta_1$, $V\theta_2$, and $V\theta_3$ of a fluid to be supplied to the actuators for the boom 11, the arm 12, and the bucket 13 in order to move along the target path at the obtained bucket inclination. Based on the computed values, flow control valves 21a, 21b, and 21c are controlled to drive cylinders 14, 15, and 16.

On the other hand, 19a is an excavating direction determining section which determines the excavating direction of the bucket 13 in accordance with the detected values $\theta_1 a$, $\theta_2 a$, and $\theta_3 a$ received from the working machine attitude detecting means 20a, 20b, and 20c, then outputs the result to the aforesaid computing means 19. The excavating direction determining section 19a determines the excavating direction by using an input value of an angle θ_2, the angle θ_2 of the arm 12 and an angle θ_1 of the boom 11, or an x-y coordinate system of the distal end of the arm 12. Specifically;

(a) When the arm angle θ_2 is used for the determination:

As shown in Fig. 14, a working area of the arm 12 is divided into two areas based on a certain arm angle θ_{20}. This reference angle θ_{20} is set in the excavating direction determining section 19a in advance, and this preset reference angle is compared with the detected value θ_2 of the arm received from the working machine attitude detecting section 20b for the arm to determine the excavating direction.

$$\theta_{20} = \varepsilon_0 \tag{6}$$

ε_0 : Set value

If $\theta_2 \leqq \theta_{20}$, then the working area will be a farther area A and the excavation will be in the pulling direction. If $\theta_2 > \theta_{20}$, then the working area will be a closer area B and the excavation will be in the pushing direction. For example, if θ_{20} = 100 [deg] and a control start point is θ_2 = 135 [deg], then $\theta_2 > \theta_{20}$, which means the area B; therefore, the excavation will be in the pushing direction. This is shown two-dimensionally in Fig. 15.

(b) When the arm angle and the boom angle are used for the determination:

As shown in Fig. 16, the following boundary which divides the working area into two areas is set in advance;

$$f(\theta_{10}, \theta_{20}) = 0 \tag{7}$$

The boom angle θ_1 and the arm angle θ_2 are substituted for the formula (7) and it is determined whether the working area belongs to the area A or the area B depending on whether the left side member is positive or negative. The excavation will be in the pulling direction in the case of the area A, while the excavation will be in the pushing direction in the case of the area B.

For example, the boundary expressed by the following formula is set:

$$f(\theta_{10}, \theta_{20}) = \theta_{10} + \theta_{20} - 160 = 0 \tag{8}$$

And if the control start point is (θ_1, θ_2) = (100, 55), then

$$f(\theta_1, \theta_2) = 100 + 55 - 160 < 0 \qquad (9),$$

and the working area is determined as the farther area A, the excavation being in the pulling direction.

(c) When conversion into the x-y coordinate system is used for the determination (part 1);

From Fig. 13, the position (x, y) of the distal end of the arm is determined by

$$x = L_1 \sin\theta 1 + L_2 \sin(\theta_1 + \theta_2),$$

$$y = L_1 \cos\theta 1 + L_2 \cos(\theta_1 + \theta_2) \quad (10)$$

And the boundary for dividing the working area into two areas as shown in Fig. 17, which is determined by the formula given below is set in advance:

$$f(x_0, y_0) = 0 \quad (11)$$

And x, y are substituted for the formula (11) and it is determined to which area the working area belongs depending on whether the left side member is positive or negative. The excavation will be in the pulling direction in the case of the area A, while the excavation will be in the pushing direction in the case of the area B.

For instance, $f(x_0, y_0) = x_0^2 + y_0^2 - 5000^2 = 0$ is set and if the control start point (x, y) is (x, y) = (7000, 200) which is determined by the formula (10), then $f(x, y) = (7000^2 + 200^2 - 5000^2) > 0$, and the working area is determined as the area A, the excavation being in the pulling direction.

(d) When the conversion to the x-y coordinate system is used for the determination (part 2);

From Fig. 18A, the position of the bucket nose with a point 0 of a boom top pin taken as the center of the coordinate is determined by

$$x = L_2 \sin(\theta_1 + \theta_2 - \theta) + L_3 \sin(\theta_1 + \theta_2 + \theta_3 - \theta) \quad (12)$$

$x_0 = 0$ is defined in advance as shown in Fig. 18B, and this is compared with the x above; if $x \geqq x_0$, then the excavation will be in the pulling direction, and if $x < x_0$, then it is in the pushing direction.

The boundary for dividing the working area into two areas, which is expressed by the formulas given above, may be fixed or it may vary according to the excavating grade or the angle of the working machine. For example, it is preset as follows: if the excavating grade is $\theta \leqq 30°$, then $\theta_{20} = 100°$; and if the excavating grade is $\theta > 30°$, then $\theta_{20} = 70°$.

In addition, if the operator wishes to optionally decide the excavating direction, a changeover switch 22 is provided as shown in Fig. 12 and the operator sets for the pulling side or the pushing side by giving priority to the signal of the external input switch. In this case, the processing flow will be as shown in Fig. 19.

According to the : embodiment, the need of entering the excavating direction among the input signals issued during excavating work is eliminated. This reduces operator fatigue from operation, preventing an operation error.

Industrial Applicability

The present invention is useful as an automatic operation mode selecting method for a working machine, which method eliminating the need of correcting the angle of a bucket nose by a user even when the bucket provided on a construction machine such as a hydraulic power shovel is replaced by any optional special bucket and enabling path control intended by an operator.

Claims

1. A method of controlling a working machine in a construction equipment, wherein a path of a distal end of a tip working machine (3) such as a bucket is automatically controlled to follow a target path by an actuator controlling meams, the tip working machine is associated with an arm (2) and the arm is associated with a boom (1), characterized in that,
automatically determining through an excavating direction determining section (19a) whether the tip working machine (3) is excavating in a pushing direction (B) or a pulling direction (A) in accordance with an operating codition which includes an attitude or a position of the tip working machine at the beginning of automatic control.

2. A method of selecting an automatic operation mode of a working machine according to claim 1, wherein giving priority to a command signal received from an external input switch (22) in the automatic determination of the excavating direction of said tip working machine (3).

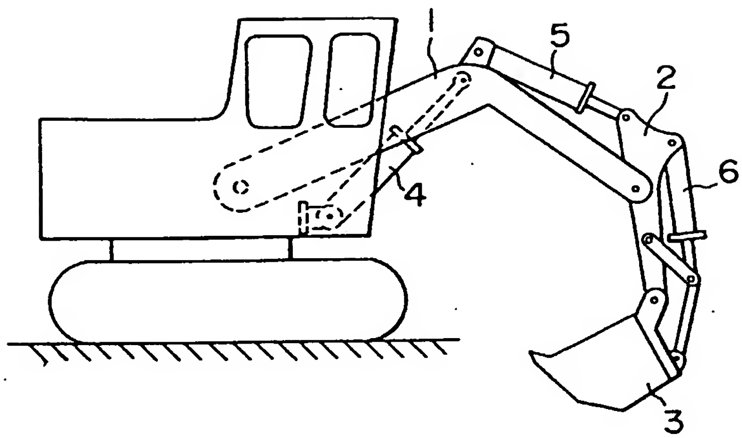

FIG. 1

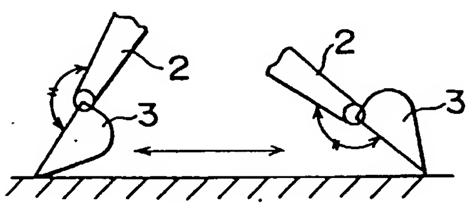

FIG. 2A

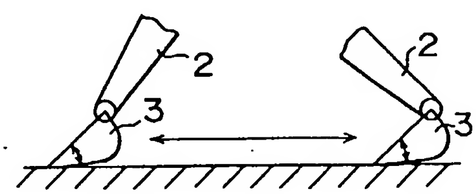

FIG. 2B

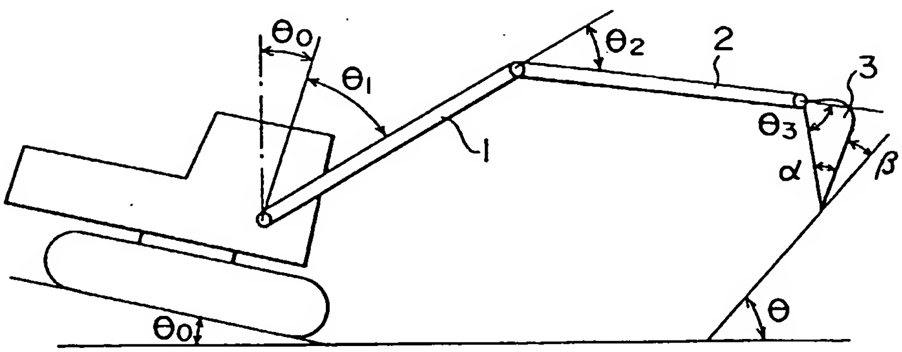

FIG. 3

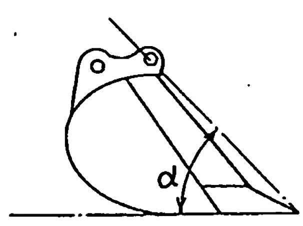

FIG. 4A

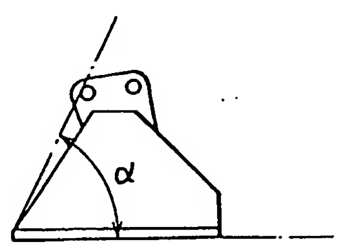

FIG. 4B

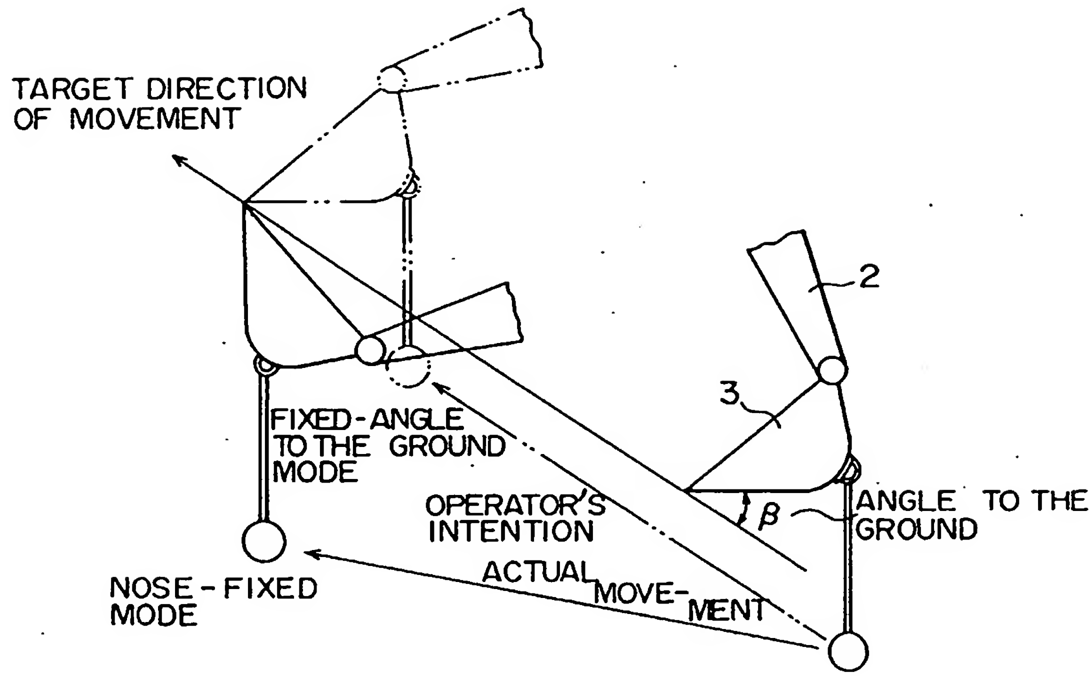

FIG.5

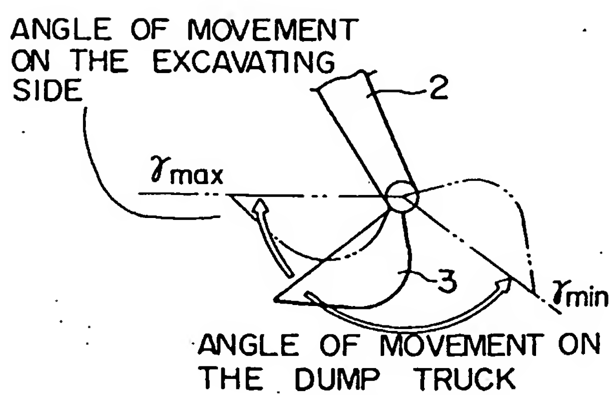

FIG.6A

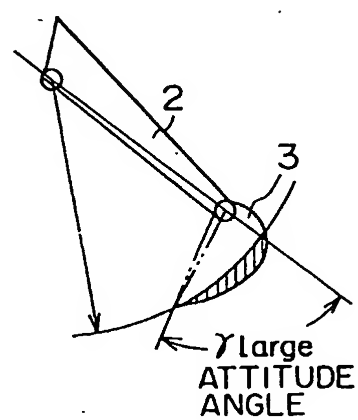

FIG.6B

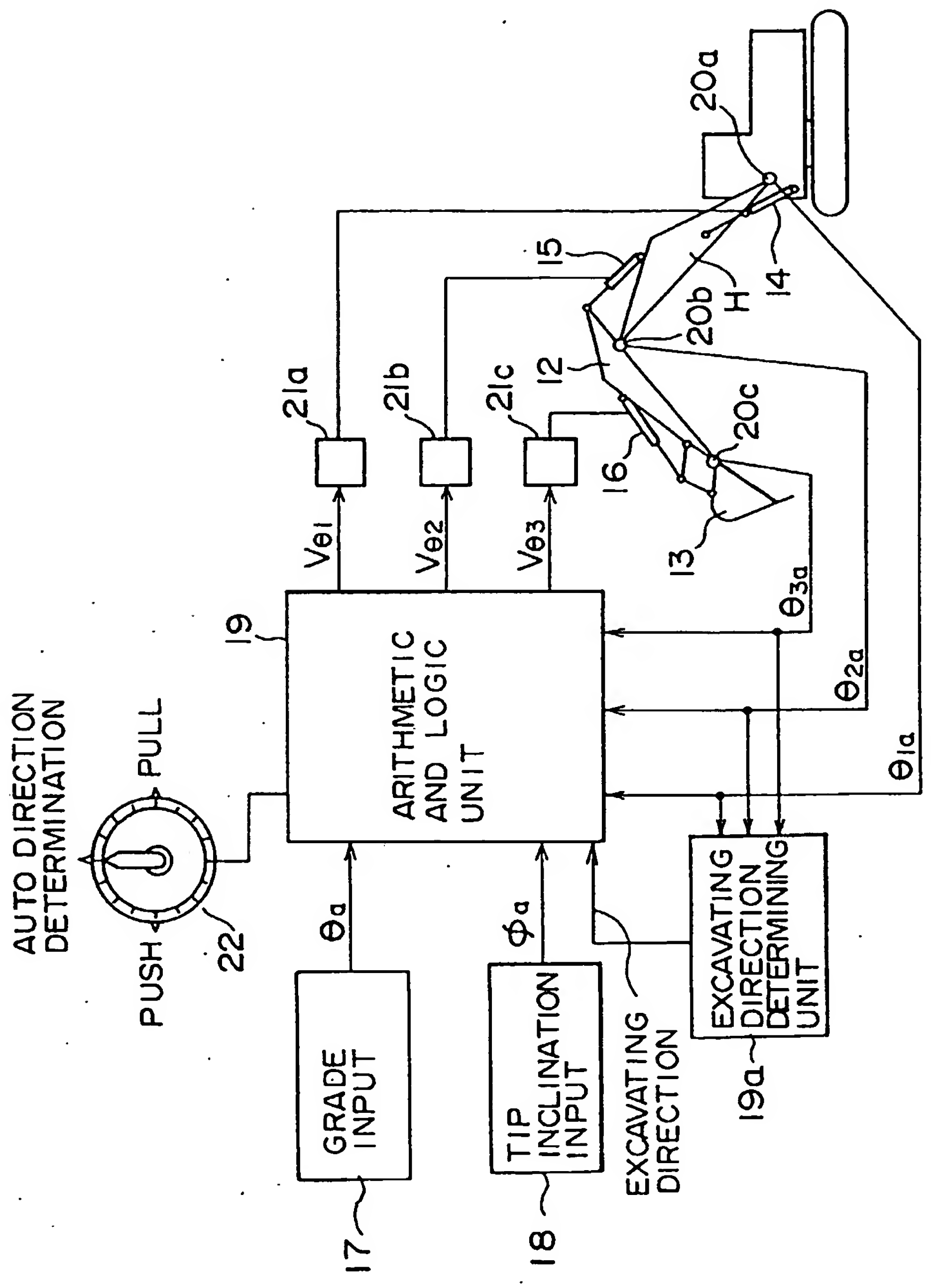
AUTO DIRECTION DETERMINATION
PUSH
PULL
22
19
ARITHMETIC AND LOGIC UNIT
GRADE INPUT
17
θa
TIP INCLINATION INPUT
18
φa
EXCAVATING DIRECTION
EXCAVATING DIRECTION DETERMINING UNIT
19a
Ve1
Ve2
Ve3
21a
21b
21c
θ1a
θ2a
θ3a
12
13
14
15
16
20a
20b
20c
H

FIG. 12

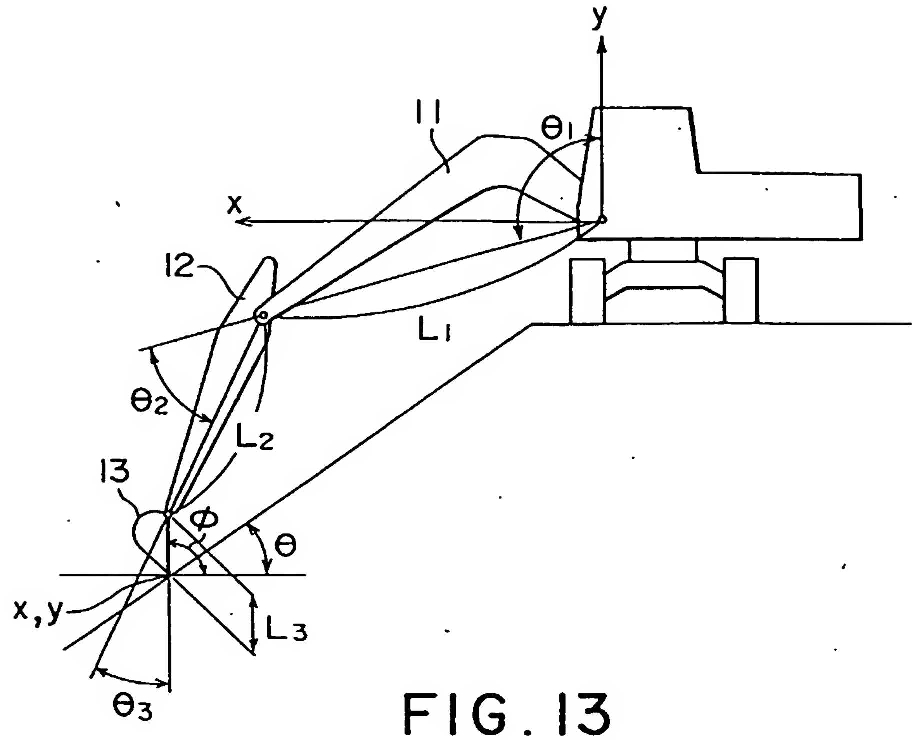
y
11
θ1
x
12
L1
θ2
L2
13
φ
θ
x, y
L3
θ3

FIG. 13

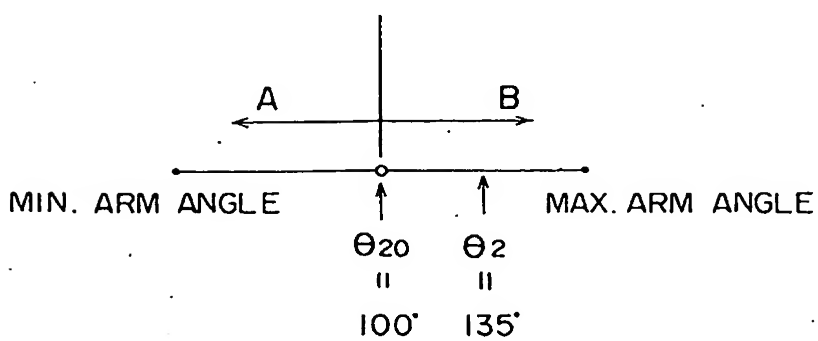
A
B
MIN. ARM ANGLE
MAX. ARM ANGLE
θ20
=
100°
θ2
=
135°

FIG. 14

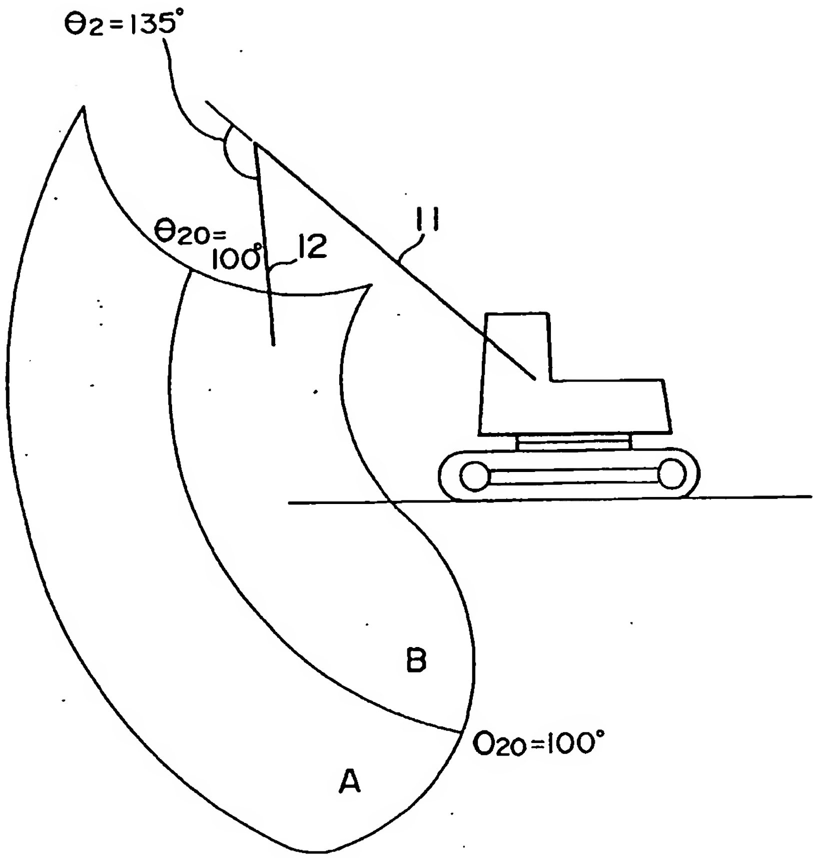

FIG. 15

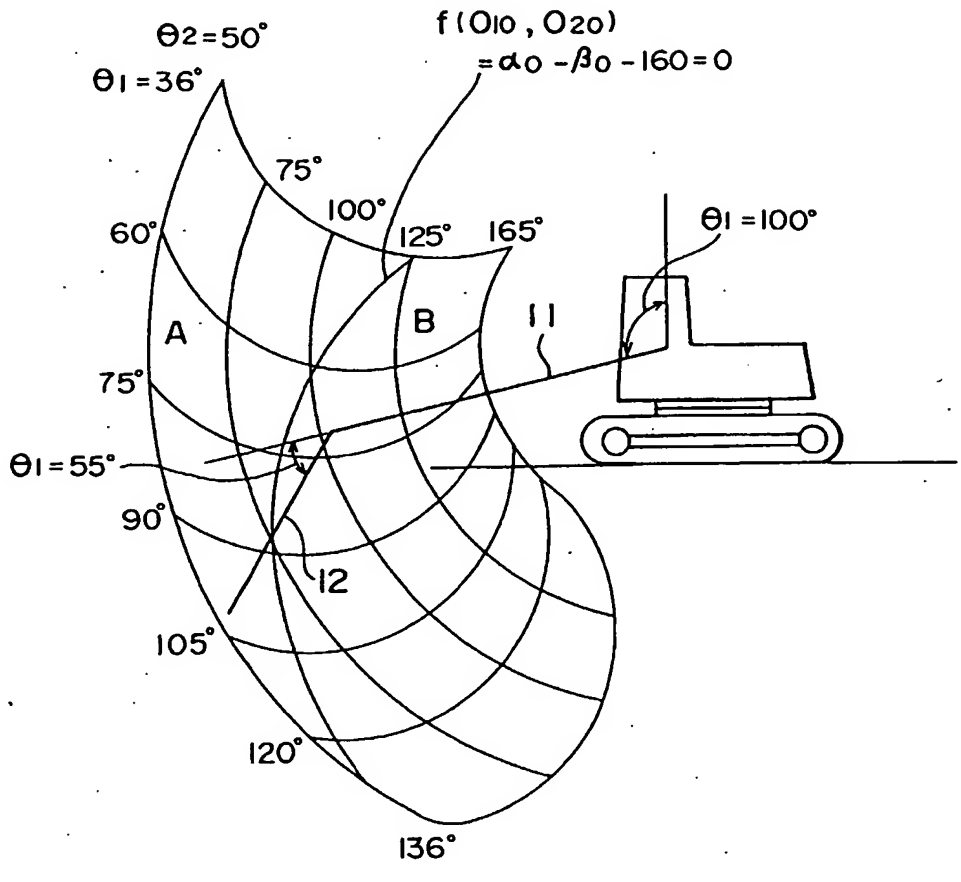
θ2=50°
θ1=36°
f(O10, O20)
=α0 -β0 -160=0
75°
100°
125°
165°
60°
θ1=100°
A
B
11
75°
θ1=55°
90°
12
105°
120°
136°

FIG. 16

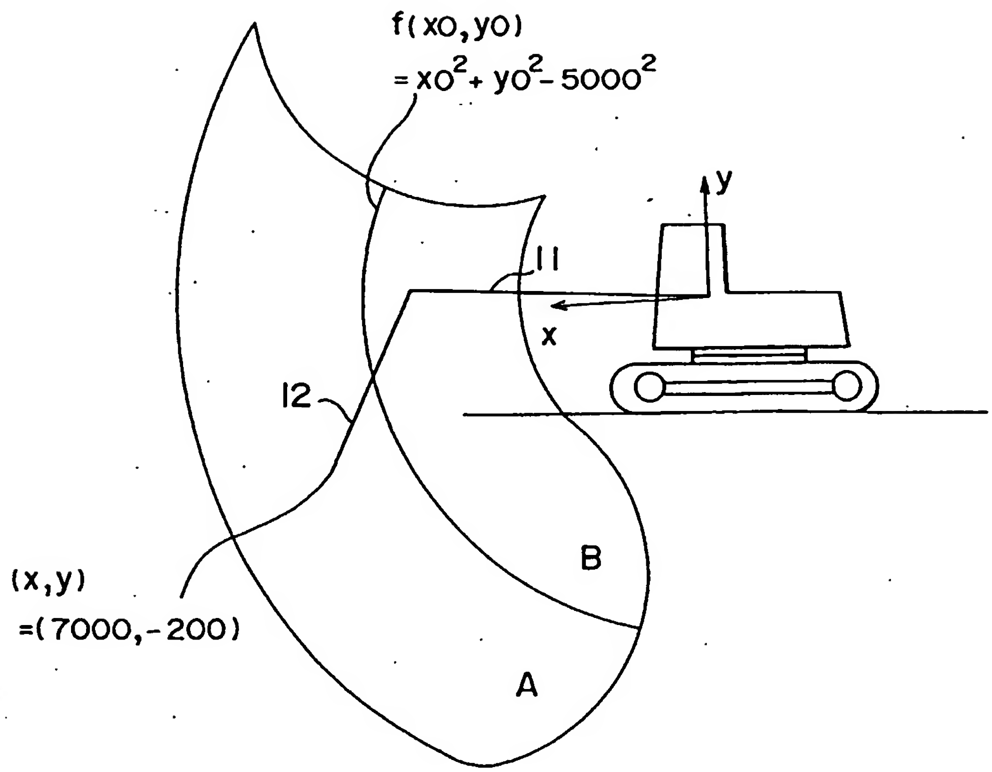

FIG. 17

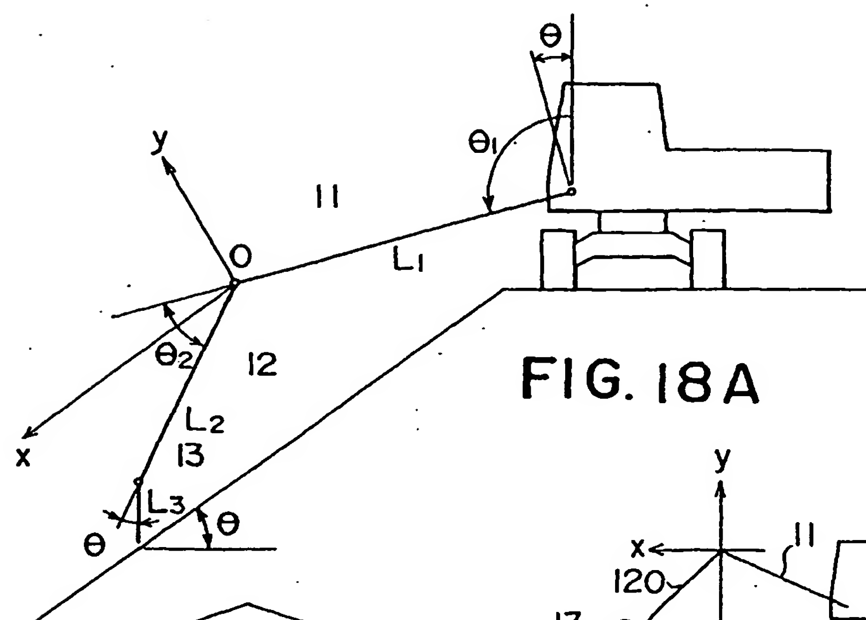

FIG. 18A

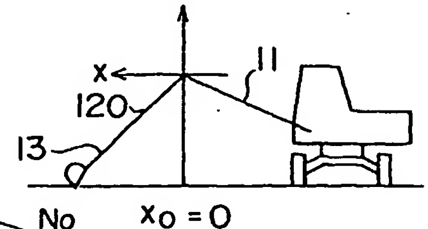

FIG. 18B

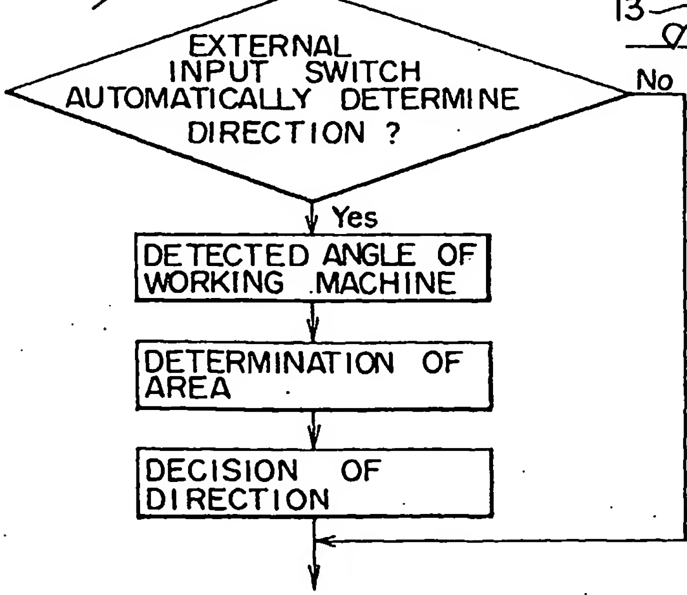

FIG. 19